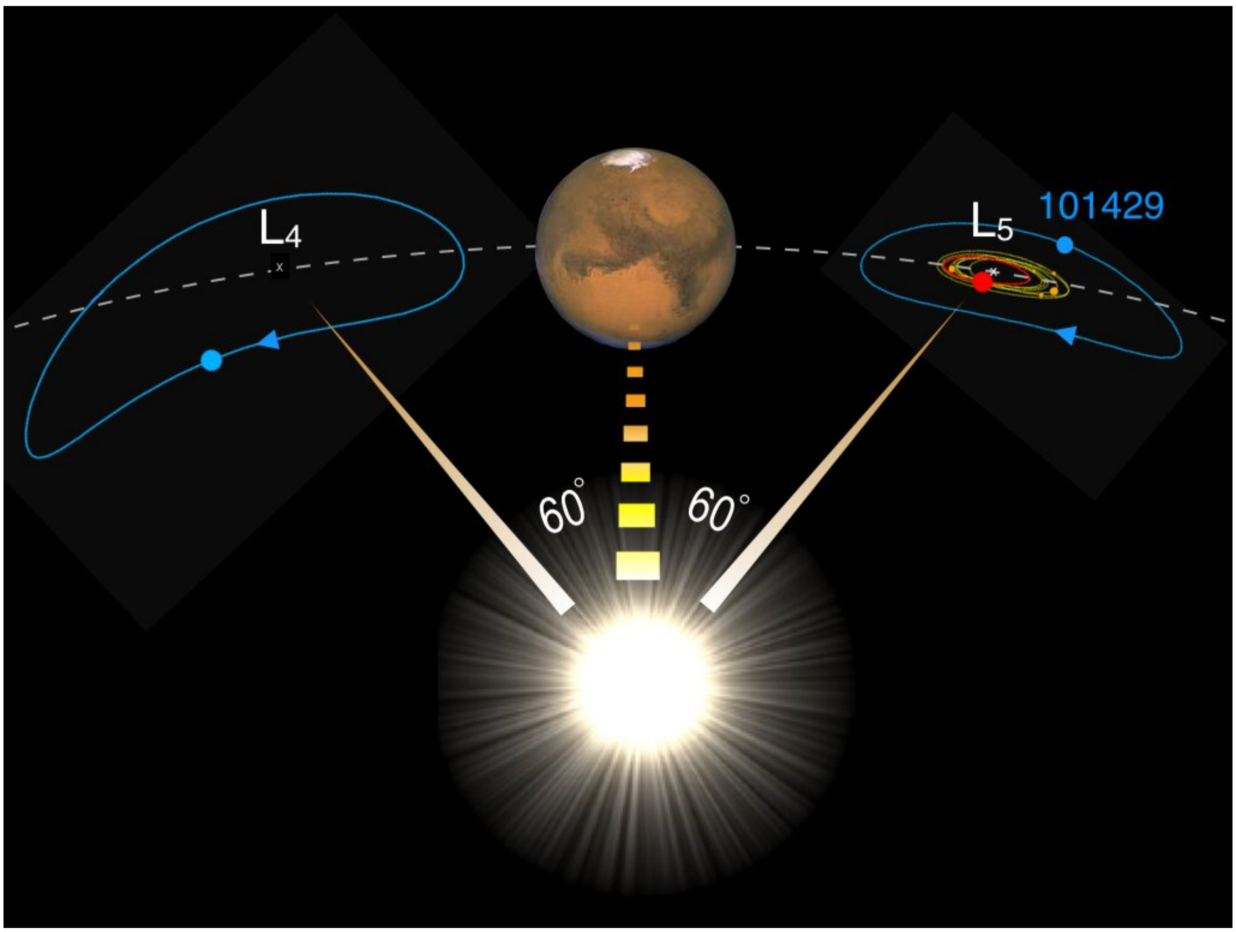
Mars plays shepherd to our moon's long-lost twin, scientists find

November 3 2020, by Apostolos Christou



Depiction of the planet Mars and its retinue of Trojans circling around the L4 and L5 Lagrange points. The dashed curve traces the planet's orbit. At L5, asteroid 101429 is represented by the blue point, the asteroid Eureka and its family are represented in red and amber respectively. Credit: Armagh Observatory

An international team of planetary scientists led by astronomers at AOP have found an asteroid trailing behind Mars with a composition very similar to the moon's. The asteroid could be an ancient piece of debris, dating back to the gigantic impacts that formed the moon and the other rocky planets in our solar system like Mars and the Earth. The research, which was published in the journal *Icarus*, also has implications for finding such primordial objects associated with our own planet.

Trojans are a class of asteroid that follows the planets in their orbits as a flock of sheep might follow a shepherd, trapped within gravitational "safe havens" 60 degrees in front of, and behind, the planet (Figure 1). They are of great interest to scientists as they represent leftover material from the formation and early evolution of the solar system. Several thousands of those Trojans exist along the orbit of the giant planet Jupiter. Closer to the Sun, astronomers have so far discovered only a handful of Trojans of Mars, the planet next door to Earth.

A team including scientists from Italy, Bulgaria and the US and led by the Armagh Observatory and Planetarium (AOP) in Northern Ireland has been studying the Trojans of Mars to understand what they tell us about the early history of the inner worlds of our solar system—the so-called terrestrial planets—but also to inform searches for Trojans of the Earth. Ironically, it is much easier to find Trojans of Mars than for our own planet because these Earth Trojans, if they exist, sit always close to the Sun in the sky where it is difficult to point a telescope. An Earth Trojan, named 2010 TK7, was found a decade ago by NASA's WISE space telescope, but computer modeling showed it is a temporary visitor from the belt of asteroids between Mars and Jupiter rather than a relic planetesimal from the Earth's formation.

To find out the composition of the Mars Trojans, the team used X-SHOOTER, a spectrograph mounted on the European Southern Observatory 8-m Very Large Telescope (VLT) in Chile. X-SHOOTER looks at how the surface of the asteroid reflects sunlight of different colors—its reflectance spectrum. By performing a spectral comparison with other solar system bodies with known composition, a process called taxonomy, the team hoped to determine if this asteroid is made by material similar to the rocky planets like the Earth, or if it is a piece of carbon- and water-rich matter typical of the outer solar system beyond Jupiter.

One on the Trojans the team looked at was asteroid (101429) 1998 VF31. Existing color data on the object suggested a composition similar to a common class of meteorites called ordinary chondrites. The light-collecting power of the VLT allowed to gather higher-quality data on this asteroid than ever before. By combining these new measurements with data obtained previously at NASA's Infrared Telescope Facility in Hawaii, the team then tried to classify 101429. They found that the spectrum did not match well with any particular type of meteorite or asteroid and, as a result, expanded their analysis to include spectra from other types of surfaces.

To their surprise, they found (Figure 2) that the best spectral match was not with other small bodies but with our nearest neighbor, the moon. As Dr. Galin Borisov, a PDRA at AOP who was deeply involved in the spectral analysis explains: "Many of the spectra we have for asteroids are not very different from the moon but when you look closely there are important differences, for example the shape and depth of broad spectral absorptions at wavelengths of 1 and 2 microns. However, the spectrum of this particular asteroid seems to be almost a dead-ringer for parts of the moon where there is exposed bedrock such as crater interiors and mountains."

Where could such an unusual object have come from? One possibility is that 101429 is just another asteroid, similar perhaps to ordinary chondrite meteorites, that acquired its lunar-like appearance through eons of exposure to solar radiation, a process called space weathering.

Alternatively, the asteroid may look like the moon because it does come from the moon. Dr. Apostolos Christou, AOP astronomer and lead author of the paper explains: "The early solar system was very different from the place we see today. The space between the newly-formed planets was full of debris and collisions were commonplace. Large asteroids—we call these planetesimals—were constantly hitting the moon and the other planets. A shard from such a collision could have reached the orbit of Mars when the planet was still forming and was trapped in its Trojan clouds."

A third, and perhaps more likely scenario is that the object came from Mars itself. As Dr. Christou points out, "The shape of the 101429 spectrum tells us that it is rich in pyroxene, a mineral found in the outer layer or crust of planet-sized bodies. Mars, like the moon and the Earth, was pummeled by impacts early in its history, one of these was responsible for the gigantic Borealis basin, a crater as wide as the planet itself. Such a colossal impact could easily have sent 101429 on its way to the planet's L5 Lagrangian point." Indeed, a Mars origin was proposed a few years ago for 101429's Trojan siblings, a cluster of Trojans collectively known as the Eureka family (Figure 1). These asteroids also have an unusual composition but, whereas 101429 is pyroxene-rich these Eureka family asteroids are mostly olivine, a mineral found deep in a planetary mantle.

101429 and its brethren also have something to teach us about finding the Earth Trojans, if they exist. Previous work by the team had shown that solar radiation causes debris, in the form of boulder- or city-block-sized chunks, from these asteroids to slowly leak out of the Trojan clouds of Mars. If the Earth Trojans are anything like Mars's, the same mechanism would act as a source of small near-Earth asteroids that will stand out because of their uncommon composition.

Finding these objects might turn out to be a job for the Vera C. Rubin Observatory, poised to begin the most ambitious survey of the solar system to-date. Rubin is expected to discover roughly ten times as many asteroids as currently known and, along with the GAIA satellite already surveying the sky from the L2 Earth-Sun Lagrange point, may offer us the best near-term prospects for tracking down the debris of Earth's Trojan companions.

More information: Apostolos A. Christou et al. Composition and origin of L5 Trojan asteroids of Mars: Insights from spectroscopy, *Icarus* (2020). DOI: 10.1016/j.icarus.2020.113994

Provided by Armagh Observatory